

ACEEE HW Forum Session 3A CO₂ HPWH for the US Market

Design and Development of
Split CO₂ HPWH for North America

John Miles – Sanden

Sanden Profile



Founded in 1943 / Revenue: \$2.8 billion / Employees: > 10,000
Global network: 54 sites in 23 countries



Automotive



Food Storage



Household



Global Facilities



Sanden International USA
Wylie Plant
Comp. for North Americas



Technical Center Europe
In Deutschland
Compressor for Europe



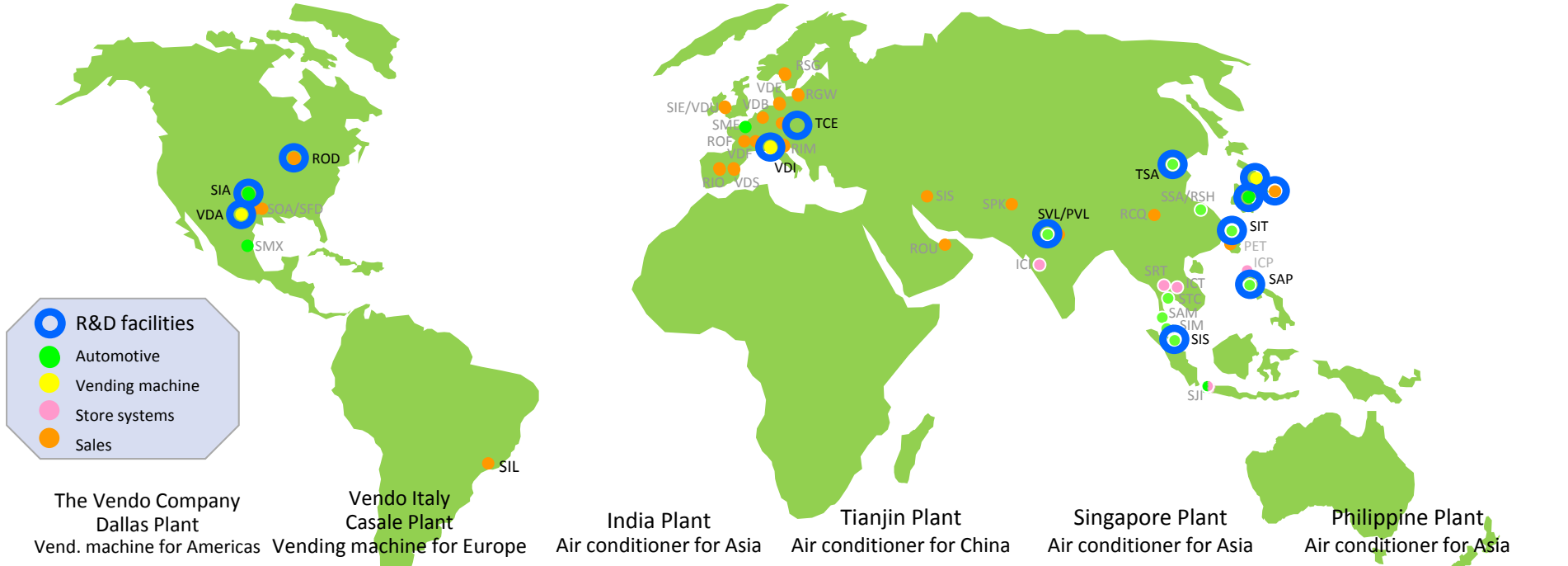
Yattajima
Automotive systems



Akagi
Vending systems



SGCT
Material & Advanced tech



The Vendo Company
Dallas Plant
Vend. machine for Americas



Vendo Italy
Casale Plant
Vending machine for Europe



India Plant
Air conditioner for Asia



Tianjin Plant
Air conditioner for China



Singapore Plant
Air conditioner for Asia



Philippine Plant
Air conditioner for Asia



Akagi Plant – Sanden Forest



**Environmental
Preservation**



**Eco-friendly Technology
Development & Manufacturing**
Heating, Cooling &
Electronics



GREEN PRODUCTS



Hybrid Compressor



Electric Driven
Compressor



CO₂ Compressor



CO₂ Heat Pump



CO₂ Cassette



Water Heater



Vending
Machine



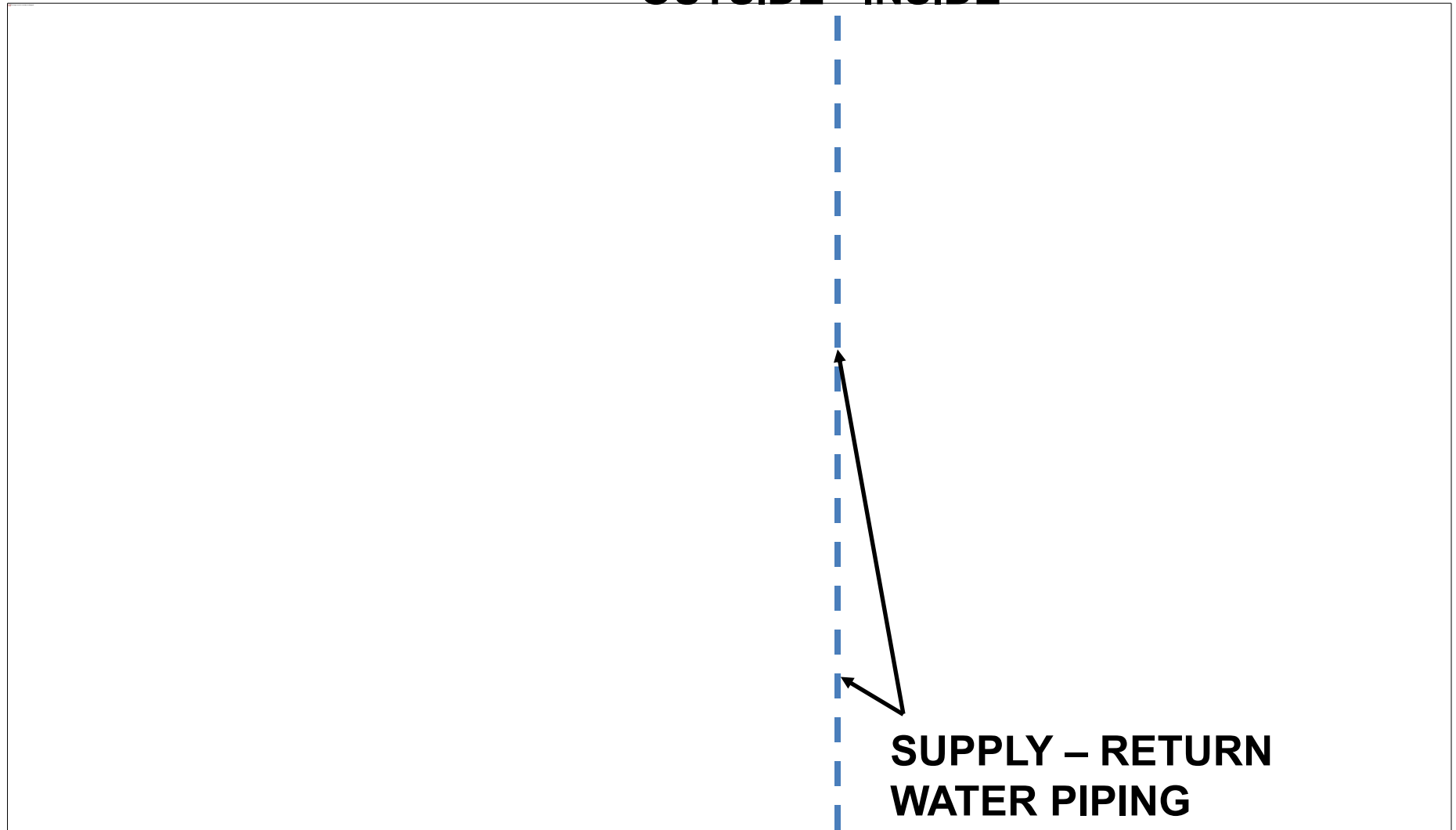
Showcase

CO₂ Split Type HPWH - History

- CO₂ Split HPWH were first designed in collaboration between Industry and University/Government Research programs in Japan during the late 90's
- Term Eco Cute was coined to describe this type of product
- First commercially available product was introduced in 2000 and Sanden launched our version of the Eco Cute product in 2006
- Eco Cute products and controls differ significantly from our Global product as cultural differences require features that are unnecessary outside of the core market

Anatomy of CO₂ Split type Heat Pump

OUTSIDE - INSIDE



Split Type Heat Pump Water Heater



Why Design a CO₂ Split type system?

Design Pro's - Performance

- Higher capacity system can produce more hot water and can meet/exceed the output of a standard electric element
- Higher efficiency – As the system is no longer constrained in size or airflow it can be optimized to improve efficiency both in the lab but more importantly for everyday operation
- Improved Performance Recovery after a draw from the system and a greater 1st hour rating on the Heat Pump

Why Design a CO₂ Split type system?

Design Pro's -

- System Airflow does not have to be dealt with inside the home – No requirement to add ductwork or venting Water Heater closet
- Internal Noise and Condensate disposal issues are removed
- Easy to install, Outdoor unit can be located up to 50ft away from the tank
- The system does not add **ANY** cooling load to the home increasing the total installed efficiency of the system

Why Design a CO₂ Split type system?

Design Con's

- System has to produce Hot Water in all ambient temperatures, especially if the system design does not include back up heater elements in the tank
- Harder to install, need to run Water pipes between the Tank and the Outdoor unit – Freeze protection
- The system does not provide cooling or dehumidification to the home

How does Sanden Design it's system

- Capacity/Efficiency/Performance in all ambient temperatures
- **Solution – Transcritical CO₂ Refrigerant cycle**
- Synthetic refrigerants such as R134a and R410A are limited in the pressure and temperatures AND efficiency they can generate especially as the ambient temperature drops
- In the Chinese market, the Split HPWH products use synthetic refrigerant so the market penetration has been geographically limited to the temperate southern regions, until the introduction of CO₂

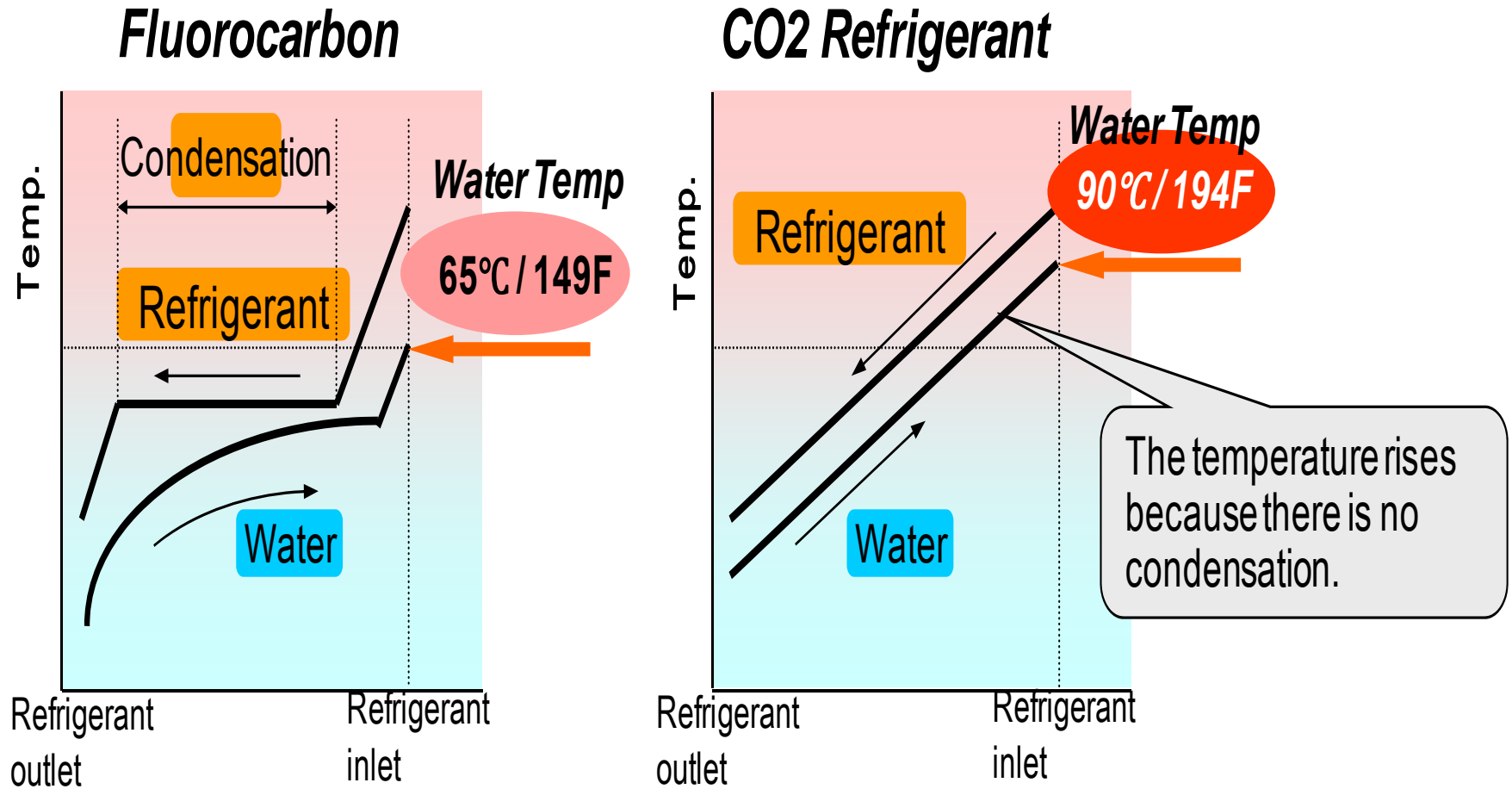
Performance vs. Temperature

Outside Air Temperature (F)	Energy Factor (EF)	COP	Output Capacity (kW)	Input Power (kW)
17	1.74	2.1	4.0	1.9
35	2.21	2.75	3.6	1.3
50	3.11	3.7	4.0	1.1
67	3.35	4.2	4.1	0.97
95	4.3	5.0	4.6	0.93

High efficiency and no capacity loss below freezing down to below zero

Transcritical CO₂

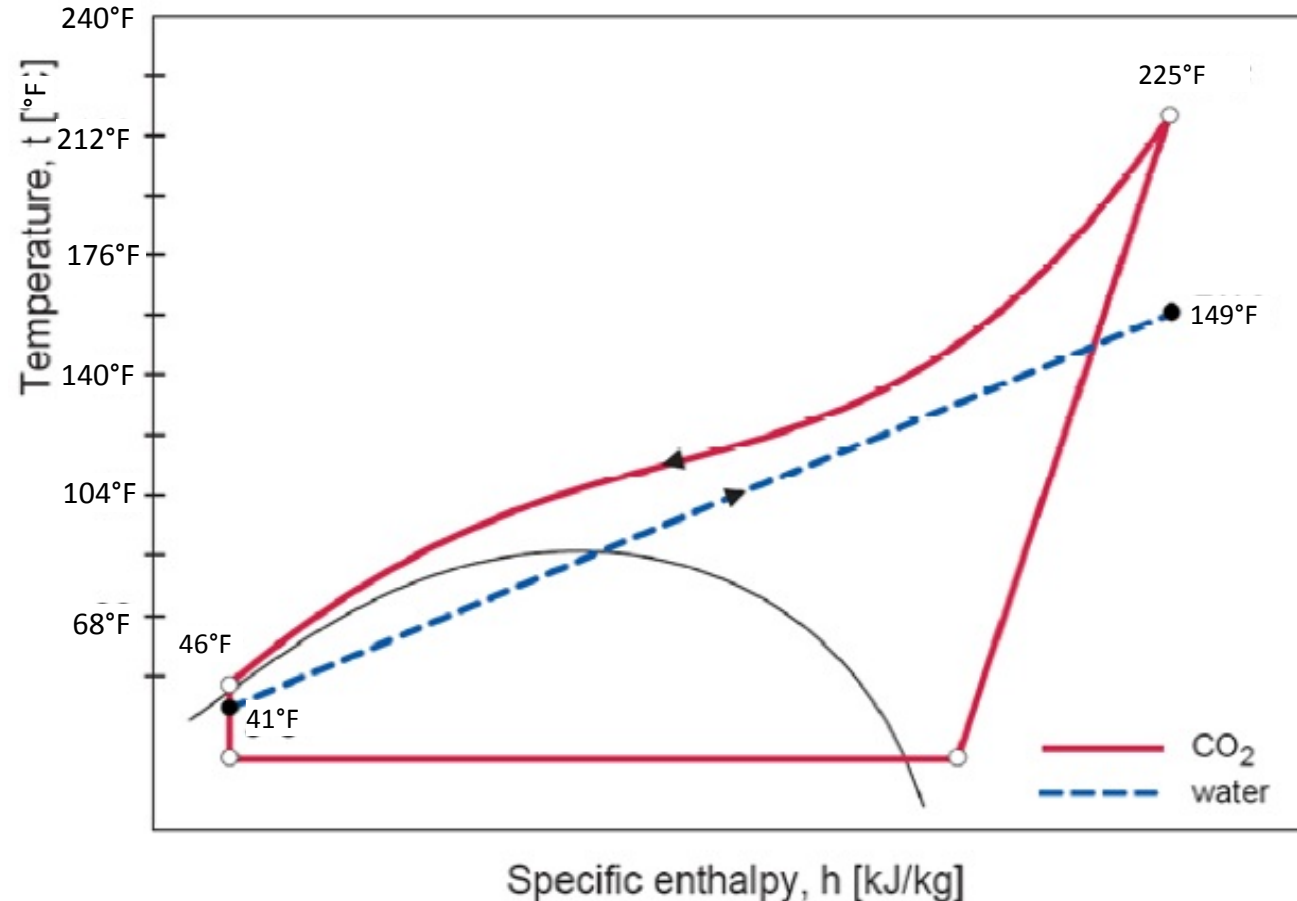
Theoretical Cycles in Water Heating



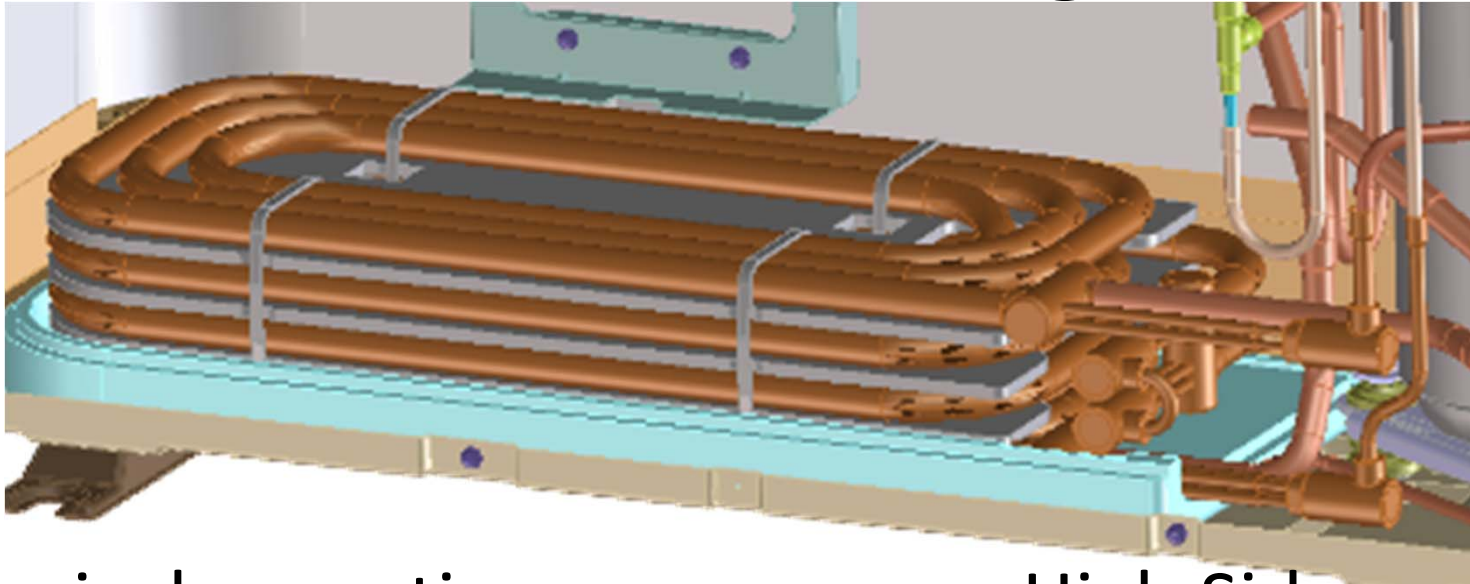
Sanden CO₂ Transcritical Cycle

- In the Transcritical cycle, the gas does not condensate in the Condenser, so it is not a typical Condenser coil but a Gas Cooler

Compression
 above
 Transcritical
 pressure
 Gas Enters into
 Gas Cooler
 Releases heat to
 the water no
 state change
 Expansion to low
 pressure (500
 psig)
 Evaporation in
 the Evaporator



Gas Cooler Design



- Typical operating pressures on High Side are approx. 1800 psig and 230°F Gas Temperature

- Double wall construction – Contra flow design

35.2 Heat exchangers intended for connection to a potable water system shall be of double wall construction and marked in accordance with Clause 38.12(a). Such design shall incorporate either a vented interface or redundant construction to prevent the leakage of refrigerant into potable water.

35.7 Heat exchangers employing a redundant double wall construction per Clause 35.2 shall have sufficient strength for each separate wall to withstand a pressure of not less than five times the maximum rated refrigerant design pressure with the outer side maintained at atmospheric pressure.

Sanden SANCO₂ Operation

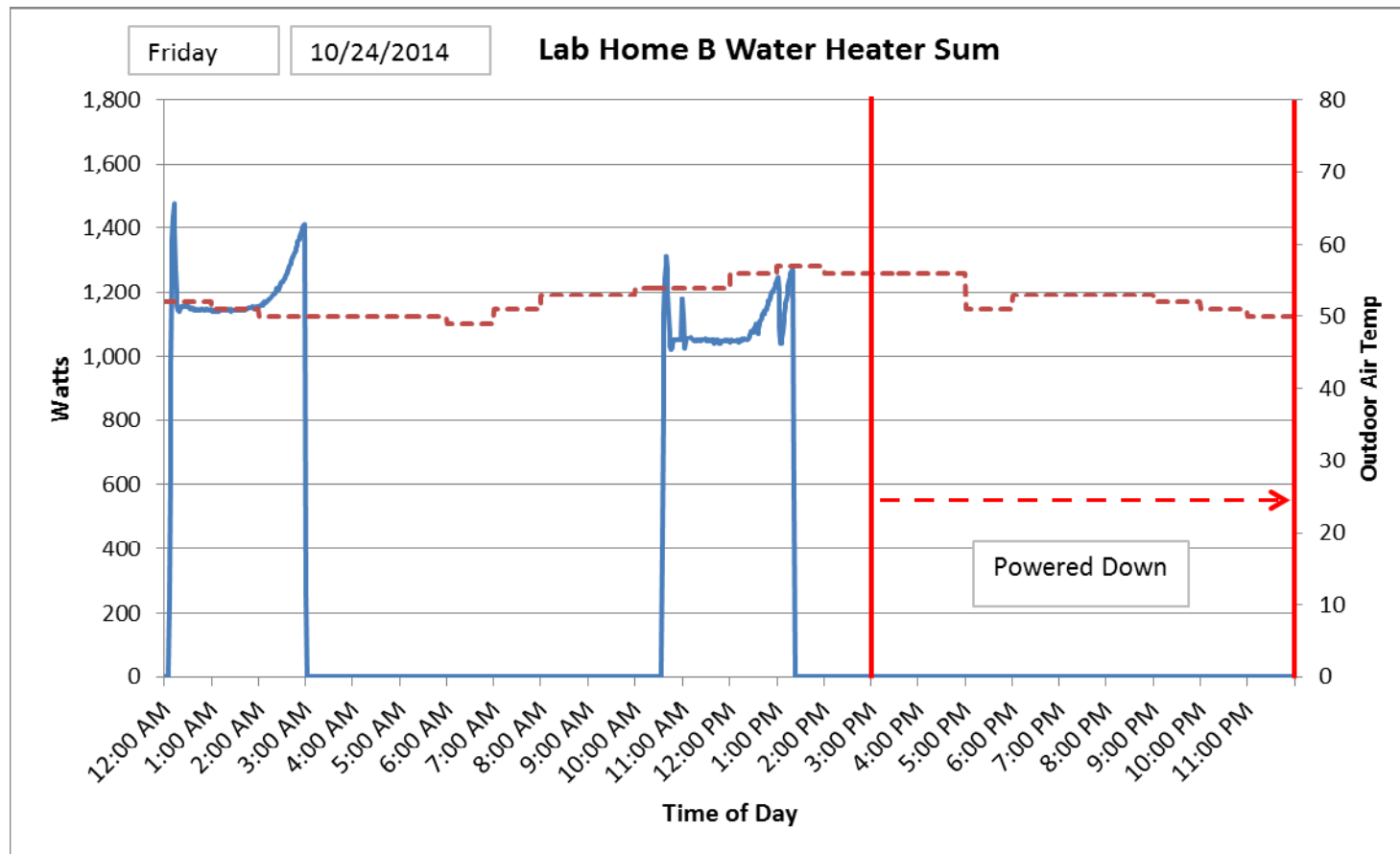
- We limit the temperature rise of water passing through the Gas Cooler and target a leaving water temperature of 149°F from the Heat Pump – At this time this is a fixed temperature
- The tank is specifically designed so the heated water from the HP is directly introduced into the top of the tank, making it quickly available to the home usage = Shorter recovery time

Sanden SANCO₂ Controls

- Single external control point – Thermistor located 2/3 from bottom of tank, only link to Outdoor
- Thermistor uses stratification of tank, we turn on HP at 113°F, turn off HP at 122°F
- Cold Water supply to the HP is from bottom 6” of tank
- Inverter compressor and variable speed pump work together to modulate HP output based on the incoming water temperature, ambient, system pressures to maintain capacity and the target temperature of 149°F

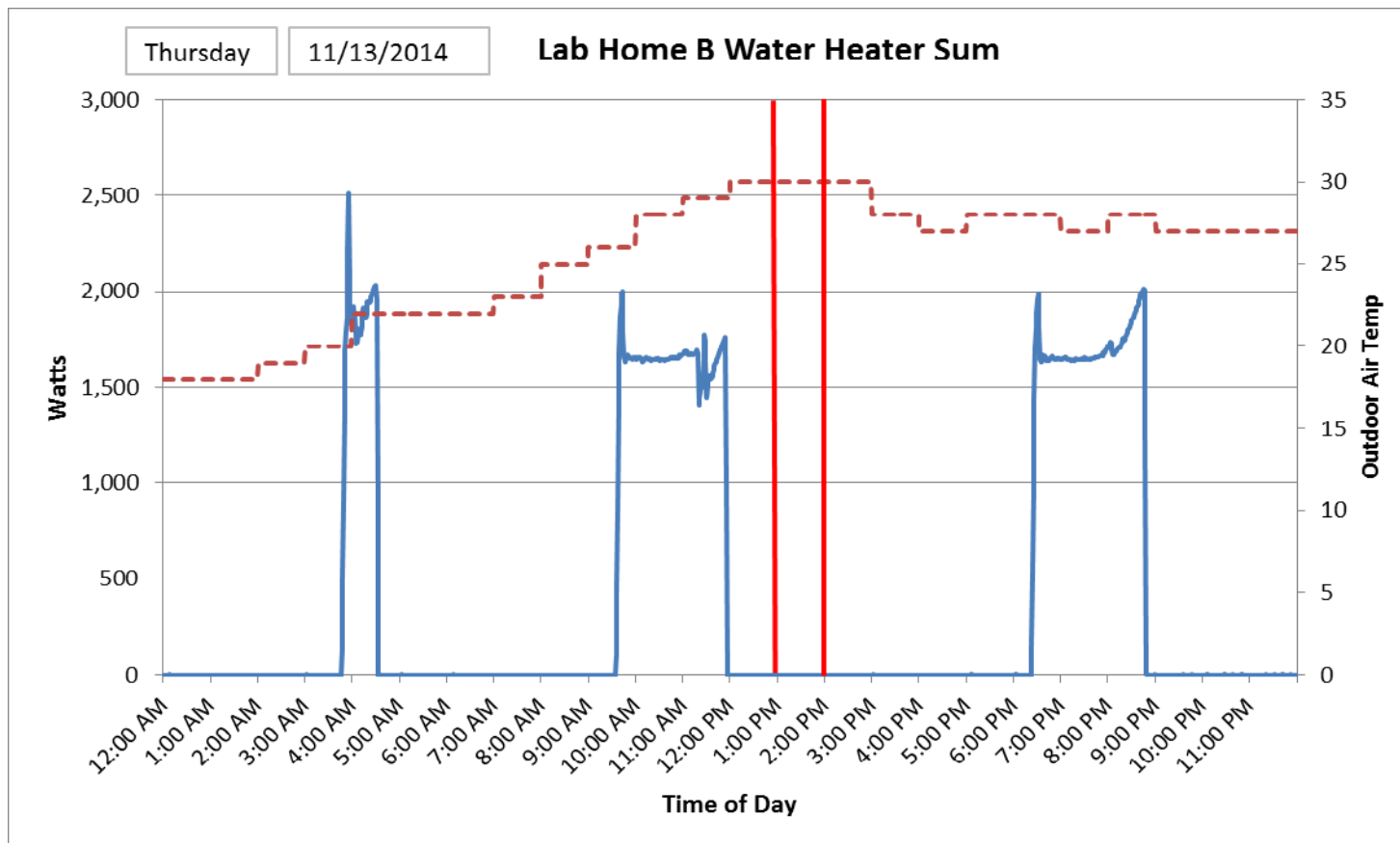
Sanden Power Consumption

These are some typical power usage curves from a testing program currently finishing up in conjunction with WSU et al



Sanden Power Consumption

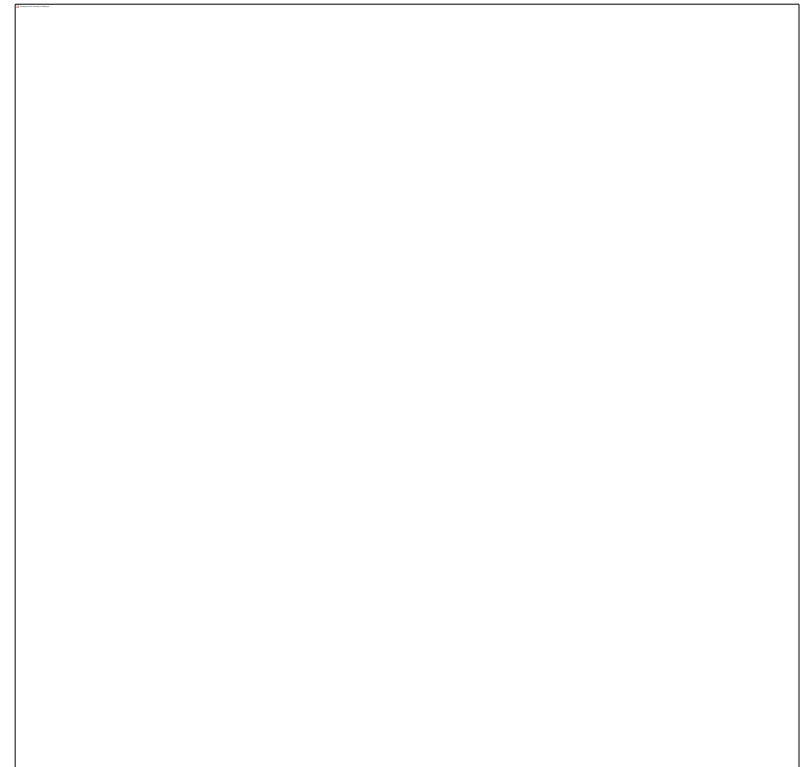
These are some typical power usage curves from a testing program currently finishing up in conjunction with WSU et al



Sanden Split System Installation

Similar to a Mini Split, but easier

- 2 x water lines – ½”
Copper/PEX from the tank connections to the Outdoor
- No Refrigeration connections
- 208/230V-1Ph @ 15A Power
– thermistor cable provided
- 50ft distance between
Outdoor and Tank
- Tank has similar connections
to a standard North American
Tank (just 2 more of them)



North American Development Strategy

- Field/Lab Testing, Pilot Sales program and more Testing
- Started our Testing program back in 2011/2012 using a Japanese Eco Cute model in conjunction with EPRI
- 2012/2013 Testing program with various other parties using the Global Split product as a base unit
- Currently working on 3 programs centered in the NW in conjunction with WSU and other parties

Pilot Sales Program



Objective:

To establish CO₂ technology awareness base by selling CO₂ split water heaters to early adopters before UL approved product launch.



Conditions:

Non UL approved base. Obtained ATAC in Portland area, working directly with other city inspectors and building departments as needed

Current Installed Base includes
Portland & other sites in Oregon
Seattle

Northern California
Monterrey, MX

Your location?



Design Changes for North America

- Core Cold Weather (Hokkaido) global design currently unchanged –Compressor, Controller, Gas Cooler, Evaporator
- Product detail changes as needed to meet the regulatory standards
- “Line Set” length increased – larger residences
- Freeze Protection/Cold Weather line set protection being optimized
- Tank design to make it easier to retrofit into the North American home

Sanden Timeline

- 2006 Introduced CO₂ Eco Cute in Japan
- 2011 Introduced CO₂ unit in Europe (Integrated type)
- 2011 Introduced Global Split in Australia
- 2012 First Test units in US
- 2013 Successful Lab and Field trials
- 2014 Pilot Sales program started
- 2015 Q2/Q3 – Full Commercial Launch of SANCO₂ Split CO₂ HPWH
- 2016 on

SanCO₂

Thank You

www.Sandenwaterheater.com